

Program Progress Report
CDRL A002

Pilot-in-the-loop Method Development

2012 Basic and Applied Research in Sea-Based Aviation

ONR #BAA12-SN-0028

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Prepared by

Combustion Research and Flow Technology, Inc. (CRAFT Tech)
6210 Keller's Church Rd.
Pipersville, PA 18947
Phone: 215/766-1520; Fax: 215/766-1524
Attn: J. Shipman
Email: shipman@craft-tech.com

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Prepared for

Naval Air Warfare Center AD
48110 Shaw Road, Code 4.3.2.1
Patuxent River, MD 20670
Arlington, VA 22203-1995
Attn: Dr. Susan Polsky, Code 4.3.2.1
Phone: 301.342.8575
Email: susan.polsky@navy.mil

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1 PROJECT OVERVIEW

The goal of this project is to integrate novel numerical modeling and computer hardware approaches to compute the non-linear aerodynamic coupling between the ship and aircraft in such a way that execution times are at real-time speeds, allowing for pilot-in-the-loop CFD to be integrated in the piloted flight simulation environment. To achieve the speed gains required, three areas will be targeted for implementation into the CFD simulation framework: (1) numerical algorithms, (2) novel domain boundaries, and (3) Graphical Processing Unit (GPU) hardware. A framework will be established to link the CFD with realtime simulations. A building block approach will be employed to first demonstrate non-realtime integration of the CFD simulation framework with helicopter flight dynamic models, then realtime execution for a minimum fidelity airwake/aircraft simulation, then build to higher fidelity realtime simulations.

1.1 Project Technical Objectives

The project involves the following seven tasks to accomplish the technical objectives of the project:

Task 1: Implement modular implicit/explicit solver

Task 2: Apply structured numerics

Task 3: Apply subdomain with immersed boundary

Task 4: Implement higher order explicit solver for GPU execution

Task 5: Integrate with the GENHEL-PSU flight dynamics model

Task 6: Demonstrate flight simulation in the PSU Rotorcraft Simulation Facility

Task 7: Demonstrate flight Simulation in NAVAIR Manned Flight Simulator

2 WORK SUMMARY

A full scale SFS2 (Simple Frigate Shape) grid was constructed based on the wind tunnel grids provided by NAVAIR. The case was tested and setup with example inputs and provided to PSU. Currently PSU researchers are generating unsteady airwake solutions on the grid using CRUNCH CFD for coupling with the GENHEL UH-60 helicopter model.

An LHD geometry was provided to CRAFT Tech for completing structured simulations for Task 2. A slightly simplified geometry was built from this model and an initial unstructured grid was constructed for running CRUNCH airwake simulations. These cases are currently underway and we are beginning to construct structured grids of the LHD case.

2.1 Full-Scale SFS2 Cases

A full-scale SFS2 grid was generated with Pointwise from the wind tunnel grids (1/100th scale) provided by NAVAIR by extracting the surface mesh and scaling up to full scale. A farfield boundary was created in place of the wind tunnel walls. The original subscale grids were created with the VGRID grid generator. Care was taken to match as closely as possible grid parameters such as edge length and wall spacing given the differences in grid generation methods of the software. “Baffle” surfaces were used in Pointwise to control the volume mesh resolution in the wake region to reproduce the source volume clustering used in VGRID. The full scale grid, shown in Figure 1 and Figure 2, had a total cell count of 2.7 million cells, after recombining anisotropic tetrahedral in the boundary layer extrusion to prisms.

The grid was tested first for steady state conditions for a 25 knot wind-over-deck. Once a converged steady state solution was obtained, the grid was tested for unsteady performance at a time step of 0.01 seconds. The unsteady airwake solution is illustrated in Figure 3.

The example input files and grids were provided to PSU. Currently, PSU researchers are running the case to generate 60 second long airwake datasets for performing initial one-way coupled integrations with the GENHEL UH-60 helicopter model.

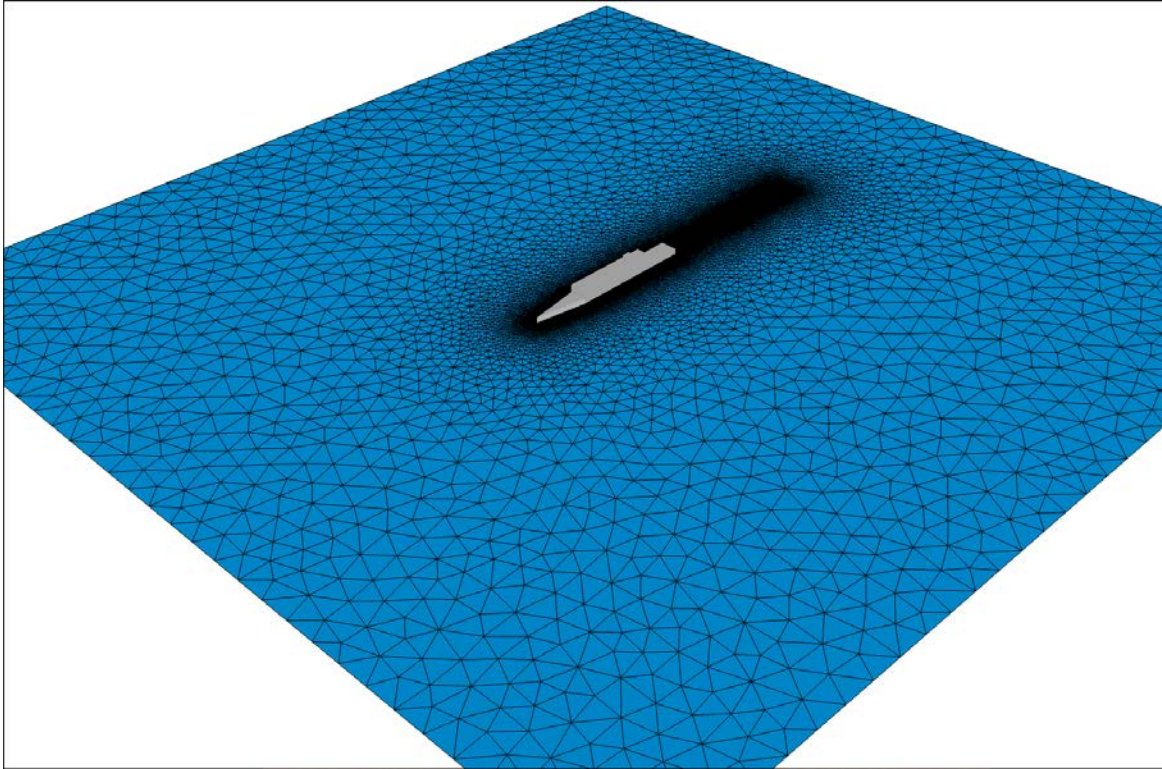


Figure 1: Full scale SFS2 geometry and grid.

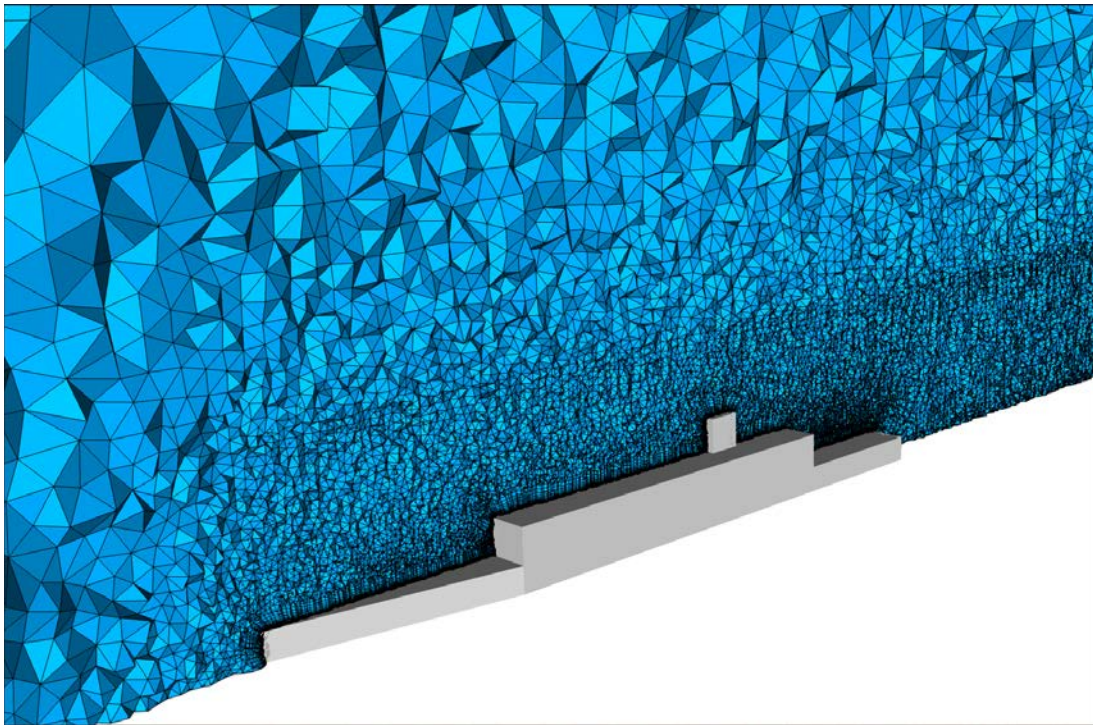


Figure 2: Close-up of volume mesh surrounding the SFS2 ship model.

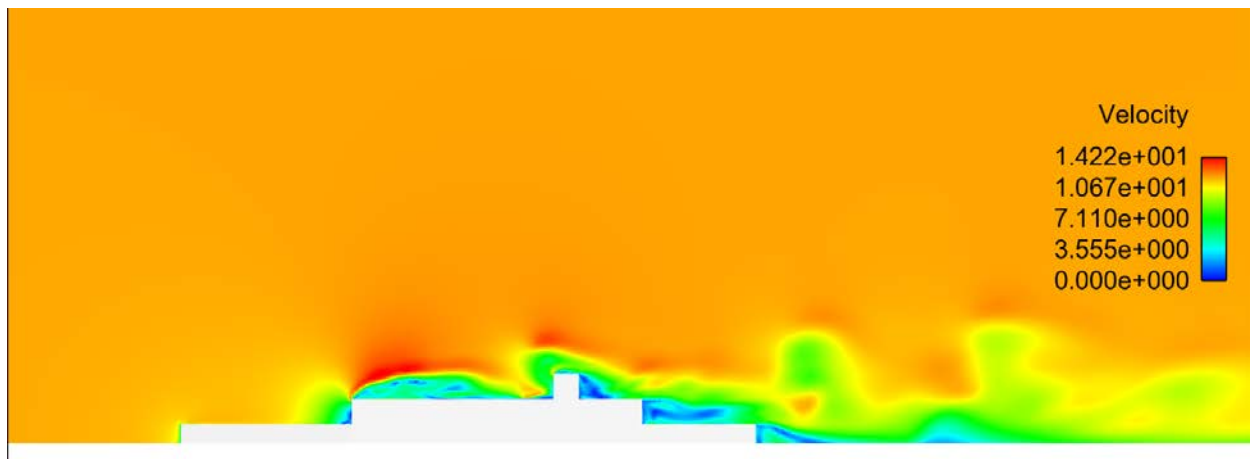


Figure 3: Velocity contours for the unsteady SFS2 airwake solution.

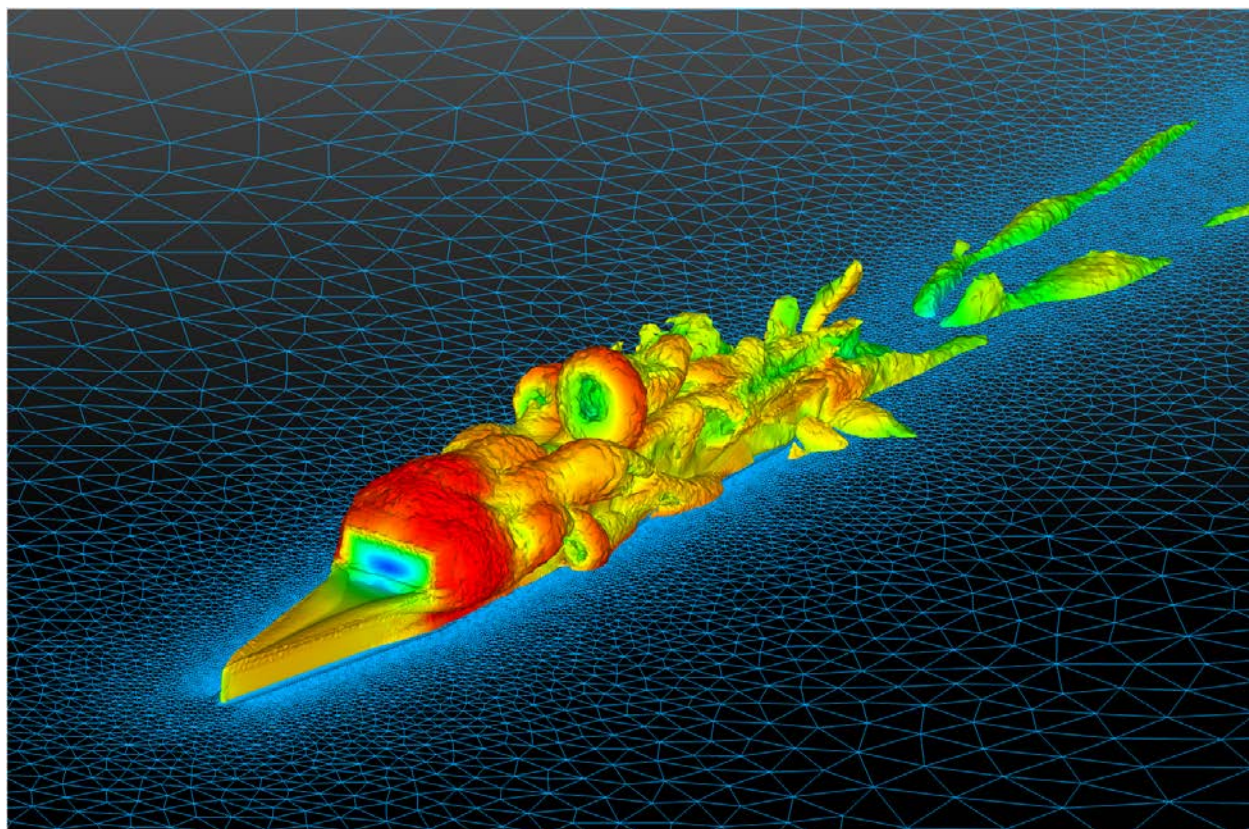


Figure 4: Isosurface of vorticity colored by velocity for the unsteady SFS2 airwake solution.

2.2 LHD Airwake Case

CRAFT Tech was provided LHD geometry in the form of IGES surfaces and boundary curves for an LHD ship case that had been constructed using the GridTool/VGRID grid generator. A simplified full scale geometry was created by creating triangulated surfaces from the boundary curves using Pointwise. Since the intended grid topology will be structured, the geometry was simplified by removing some of the smaller surfaces such as turrets, elevators, and smaller features on the hull and superstructure.

Initially, a relatively small unstructured grid was generated for this geometry consisting of about 4 million cells, as shown in Figure 5. The case is currently underway and will be presented in the next report. The next step will be to generate a structured grid (target of about 10 million cells) as well as a larger unstructured grid for performance comparisons. The structured LHD calculation, once verified with the “best practices” unstructured calculations, will be the baseline structured calculation for performing speed-up solver development going forward.

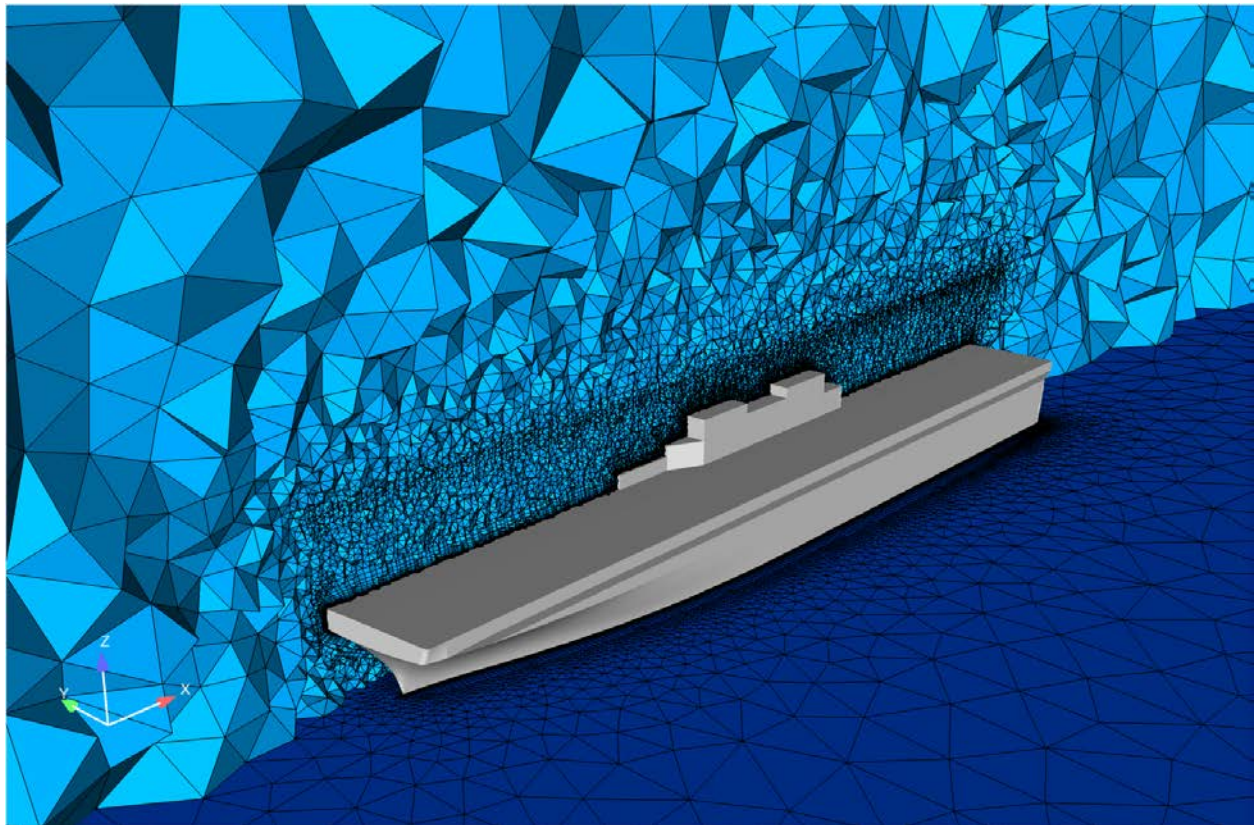


Figure 5: LHD geometry and unstructured grid.

3 TECHNICAL/COST STATUS AND PROBLEM AREAS

No technical or financial problems have been encountered.

4 MEETING AND/OR TRAVEL

N/A

5 CONTRACT SCHEDULE

The program is proceeding as planned.

6 PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

In the next period, initial unstructured calculations will be completed for the LHD airwake case. A structured grid with a target size of 10 million cells will be constructed. Structured calculations with that CRAFT CFD standard solver will be performed and as a baseline solution to compare with larger unstructured calculations.

Discussions with PSU researchers have taken place regarding a plan for integrating GENHEL with the CFD airwake. Initially this will be performed using CRUNCH CFD solutions generated at PSU (for the SFS2 ship calculation) for one-way coupled simulations. Eventually we will progress to fully coupled simulations which will require coordination with NAVAIR to define the communication protocols developed for previous CASTLE/Kestrel coupling.

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